⑫ EUROPEAN PATENT APPLICATION

㉛ Applicant: ANSALDO SISTEMI INDUSTRIALI S.p.A.
Via Pieragostini, 50
I-16151 Genova Ge(IT)

㉛ Applicant: INNSE INNOCENTI SANTEUSTACCHIO
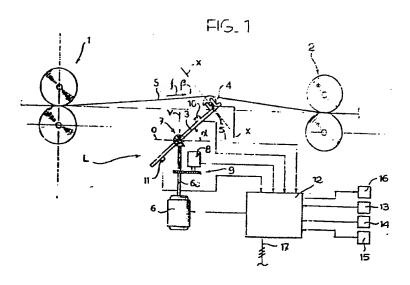S.p.A.
20, Via A. Franchi
I-25127 Brescia(IT)

㉜ Inventor: Casavola, Felice
Via Agave 11/3
I-17019 Varazze (Savona)(IT)

㉜ Inventor: Zanicotti, Luciano
Via Tolstoi 74
I-20146 Milano(IT)

㉞ Representative: Vannini, Torquato et al,
JACOBACCI-CASETTA & PERANI S.p.A. 7 Via Visconti di
Modrone
I-20122 Milan(IT)

㊹ Device for regulating the draught of the strip in a hot rolling mill.

㊼ The device includes an arm (3) pivotable about an axis parallel to the strip (S) and perpendicular to the direction of advance of the strip. One end of the arm is held in contact with the strip and carries a sensor (5) which outputs electrical couple signals indicative of the couple (Q_L) applied by the strip to the arm about the pivot axis of the arm. A processing and control unit (12) is connected to the couple sensor and to sensors (8) for sensing the angular position of the arm, and is arranged to generate an error signal (ε_c) in dependence on the difference between the said couple signals (Q_L) and a reference couple signal (Q_N). The device further includes drive means (6) arranged, when actuated, to change the position of the tensioner (3) in dependence on the error signal (ε_c) generated by the control and processing unit.

EP 0 161 223 A2

./...

FIG. 1

Device for regulating the draught of the strip in a hot rolling mill

The present invention relates to a draught regulating device for finishing stands of hot rolling mills for maintaining the tension or draught of a strip between two consecutive rolling stands substantially constant in

5 order to obtain rolled strips with the optimum technological qualities.

In particular the invention relates to a device for regulating the draught of the strip in a rolling mill comprising

10 - a tensioning arm pivotable about an axis parallel to the strip and perpendicular to the direction of advance of the strip, having one end intended to be kept in contact with the strip and carrying sensor means for sensing the force applied by the strip to the arm,

15 - means for sensing the angular position of the arm,
- a processing and control unit connected to the force sensor means and to the position sensor means, and
- drive means arranged, when actuated, to change the angular position of the arm and hence the tension or

20 draught of the strip in dependence on the signals provided by the processing and control unit.

The object of the present invention is to provide a draught regulating device of the said type which is very precise, very reliable with a considerable speed of

25 response, while being simple and economical to manufacture and put into operation.

This object is achieved according to the invention by means of a draught regulating device of the type specified above, the main characteristic of which lies

in the fact that the force sensor means are arranged to output an electrical couple signal indicative of the couple applied by the strip to the arm about the said axis,

5   and in that the processing and control unit is arranged to output an error signal in dependence on the difference between the couple signal and a reference couple signal; the unit including regulating means arranged to actuate drive means in dependence on the

10   error signal.

Further characteristics and advantages of the draught regulating device according to the invention will become apparent from the detailed description which follows with reference to the appended drawings, provided purely

15   by way of non-limiting example, in which:

Figure 1 is a schematic view of a draught regulating device according to the invention, and

Figure 2 is a block electrical diagram of the device of Figure 1.

20   With reference to Figure 1, a strip S is shown advancing in the direction of the arrow f from a first stand of rolls 1 of a rolling mill to a second stand of rolls 2. Intermediate the stands of rolls, beneath the strip S, is a strip tensioning device (looper) according to the

25   invention, generally indicated L. This device comprises a tensioning arm 3 pivotable about an axis parallel to the strip S and perpendicular to the direction of advance f of the strip. The pivot axis of the tensioning arm 3 is shown in Figure 1 by the

30   intersection between the horizontal plane O and the

vertical plane V.

The tensioning arm 3 carries at one end a load cell 5 of conventional type, for example of the magnetostriction effect type, which cooperates with a roller 4 kept in contact with the lower face of the strip S and able to move solely along a circular arc β.

In operation, as the tension to which the strip S is subject varies, the force exerted by the roller 4 on the load cell 5 varies.

The tensioning arm 3 may be rotated about the pivot axis defined above by means of an electric motor 6 for example of the direct current type, and a pair of bevel gears 7. The shaft 6a of the electric motor 6 is coupled to the input shaft of an angular position electric transducer 8 through a reduction gear 9. The transducer 8 is preferably a rotary electromagnet analogue transducer of the known type commonly termed a resolver and outputs, as will be clarified below, electrical signals proportional to $\sin\alpha$ and $\cos\alpha$, α being the angle between the tensioning arm 3 and the horizontal plane O, as indicated in Figure 1.

On opposite sides of its pivot axis, and preferably at the same distance from the axis, the tensioning arm 3 carries two accelerometers 10, 11 which, in operation, provide electrical signals proportional to the angular acceleration α'' of the tensioning arm 3.

The device according to the invention further includes a processing and control unit generally indicated 12 in Figure 1 and illustrated in greater detail in Figure 2.

0161223

This unit is connected to the load cell 5, the transducer 8 and the accelerometers 10, 11.

The processing and control unit 12 is also connected to the electric motor 6.

5   The processing unit 12 is also connected to a manually operable input device 13 for providing the unit with an electrical signal indicative of a reference value (nominal value) of the tension or draught of the strip S. This device may 13 be constituted simply by a

10   potentiometer.

To the control and processing unit 12 there are also connected further manually operable input devices 14 and 15 for providing the unit 12 with electrical signals indicative of couple values proportional to the weight

15   of the strip S and to the weight of the tensioning arm 3 for purposes which will be clarified below.

Finally the processing and control unit 12 is connected to an output device 16, for example a visual display device for providing an indication of the tension or

20   draught effectively acting at any moment on the strip S.

The processing and control unit 12 is also connected to or is connectible to the mains network through a supply line indicated 17 in the drawings.

As will become apparent from the description which

25   follows with reference to Figure 2, the processing and control unit 12 is arranged to regulate the current supplied to the electric motor 6 in dependence on the signals provided by the load cell 5, the position

transducer 8, the signals output by the accelerometers 10 and 11, the values input by means of the devices 14 and 15 and the nominal tension or draught input by the device 13. The supply current for the motor 6 is

5   adjusted when necessary to modify the position of the tensioning arm 3 and hence the draught of the strip S in order to maintain this tension substantially constant and as equal as possible to the nominal tension or draught.

10   Before the detailed description of the embodiment of the control and processing unit 12 illustrated in Figure 2, several theoretical considerations at the root of the invention will be put forward.

The inventors have shown that the component of the force

15   exerted between the strip S and the load cell 5 (through the roller 4) in operation, along the axis X-X, is substantially proportional to the function

$$T_m \sin\alpha . \cos\alpha$$

where T_m is the instantaneous tension or draught to

20   which the strip S is subject and α is the angle shown in Figure 1.

As is immediately seen, the component of this force along the axis X-X is just that component which acts on the tensioning arm 3 and gives rise to a couple about

25   the pivot axis of this arm. This couple, which will be indicated below as Q_L, is thus also proportional to the function given above and hence may be written:

$$Q_L = k . T_m . \sin\alpha . \cos\alpha$$

in which k is a constant dependant on the geometry of

30   the system shown in Figure 1 and in particular on the distance between the stands of rolls 1, 2 and the length

of the tensioning arm 3. By virtue of the arrangement described above, the signal output by the load cell 5 is thus indicative of the couple Q_L applied by the strip S to the tensioning arm 3 about the pivot axis of the tensioning arm.

The processing and control unit 12 includes two analogue multipliers 20, 21 and a divider 22. The multiplier 20 has its inputs connected to the outputs of the position transducer 8. Its inputs are thus fed with signals proportional to the absolute value of $\sin\alpha$ and $\cos\alpha$ respectively. The signal output by the multiplier 20 is thus proportional to the absolute value of $\sin\alpha . \cos\alpha$. This signal is fed to the divider 22 and to the multiplier 21. This latter is also fed with the signal T representing the reference tension or draught (nominal draught) input for the strip S through the input device 13. The multiplier 21 thus outputs a signal Q_N

$$Q_N = k'.T.\sin\alpha.\cos\alpha$$

The output of the divider 22 in operation is thus a signal proportional to the ratio

$$Q_L/\sin\alpha.\cos\alpha$$

and is hence proportional to the effective tension or draught acting on the strip S (measured draught). The visual display device 16 thus provides a visual indication of the effective value of the draught measured on the strip.

The signals Q_L and Q_N are also fed to an integrating draught couple regulator 23. This device outputs a couple error signal

$$\varepsilon_c = k.\int(Q_N - Q_L) \, dt$$

The signal indicative of the couple error is supplied to a first input of a summer 24. This summer is also supplied with the signal Q_N and the signals output by the input devices 14 and 15 which, as stated above, represent fixed couple values proportional to the weight of the strip S and the weight of the tensioner 3.

The signals output by the accelerometers 10, 11 are passed to a processing circuit 25 (for example an amplifier-subtractor) which outputs a signal indicative of the inertial couple C_J

$$C_J = (d^2\alpha/dt^2).J$$

where t represents time and J is the moment of inertia of the tensioning arm 3 about the pivot axis.

The summing circuit 24 in practice effects the algebraic sum of the reference couple Q_N of the couple error ε_c, the inertial couple C_J and the couples due to the weight of the strip and to the weight of the tensioner. The overall couple resulting is equal to the couple which the motor 6 must supply. This couple, as is known, for a direct current motor with independent, fixed energisation is proportional to the current I which must be supplied to the motor.

In conclusion, the output signal I of the summer 24 is proportional to the current needed for the electric motor 6 to supply a couple such as to allow, through the tensioner 3, the maintenance of a draught on the strip substantially equal to the nominal value. The signal I is supplied to a current regulating circuit 26 of known type which, through a full-wave controlled rectifier 27 regulates the current to the electric motor 6.

Although reference has been made to the use of only one load cell 5 in the description above, clearly two or more load cells 5 may be used in cooperation with the roller 4.

5   Naturally, the principle of the invention remaining the same, the embodiments and details of realisation may be varied widely with respect to those described and illustrated purely by way of non-limiting example without thereby departing from the scope of the present
10   invention.

0161223

CLAIMS

1. Device for regulating the draught of the strip in a rolling mill comprising

a tensioning arm (3) pivotable about an axis parallel to the strip (S) and perpendicular to the direction of advance of the strip, having one end intended to be kept in contact with the strip and carrying sensor means (5) for sensing the force applied by the strip (S) to the arm (3),

means (8) for sensing the angular position of the arm (3),

a processing and control unit (12) connected to the force sensor means (5) and to the position sensor means (8), and

drive means (6) arranged, when actuated, to change the angular position of the arm (3) and hence the tension or draught of the strip (S) in dependence on the signals provided by the processing and control unit (12),

characterised in that

the force sensor means (5) are arranged to output an electrical couple signal indicative of the couple (Q_L) relative to the said axis applied by the strip (S) to the tensioning arm (3),

the processing and control unit (12) is arranged to generate an error signal (ε_c) in dependence on the difference between the couple signal (Q_L) and a reference couple signal (Q_N); and

the processing and control unit (12) includes regulating means (26, 27) arranged to actuate the drive means (6) in dependence on the error signal (ε_c).

2. Device according to Claim 1, characterised in that

the force sensor means comprise load cells (5) carried by the end of the tensioning arm (3) facing the strip (S) in fixed positions relative to this arm, and arranged to provide an electrical force signal indicative of the force exerted by the strip (S) on the arm (3) in a direction (X-X) normal to the arm (3).

3. Device according to Claim 2, characterised in that the processing and control unit (12) includes generator means (13, 8, 20, 21) for generating a reference couple signal (Q_N) proportional to a predetermined tension or draught value (T) of the strip (S) and variable in dependence on the angular position of the tensioning arm (3).

4. Device according to Claim 3, characterised in that the generator means (13, 8, 20, 21) are arranged to generate a couple reference signal (Q_N) proportional to the function $T.\sin\alpha.\cos\alpha$, where T is the predetermined value of the tension of the strip (S) and α is the angle between the tensioning arm (3) and the horizontal plane (0).

5. Device according to any one of the preceding claims, characterised in that it further includes measuring means (20, 16) for providing electrical signals indicative of the instantaneous effective tension in the strip (S), the measuring means including a divider device (22) connected to the force sensor means (5) and to the means for sensing the position of the arm (8, 20) and arranged to output a tension signal proportional to the ratio between the couple signal (Q_L) and the function $\sin\alpha.\cos\alpha$, where α is the angle between the tensioning arm (3) and the horizontal plane (0).

6. Device according to Claim 4 or Claim 5, characterised in that the means for sensing the angular position of the tensioning arm (3) include a rotary electromagnetic analogue transducer (resolver) (8) kinematically coupled to the tensioning arm (3), and arranged to generate first and second electrical signals proportional to $\sin\alpha$ and to $\cos\alpha$ respectively and the processing and control unit (12) includes a first multiplier device (20) connected to the transducer (8) and arranged to output a signal proportional to $\sin\alpha.\cos\alpha$.

7. Device according to Claims 4 and 6, characterised in that it further includes a generator (13) of a D.C. voltage which is variable by means of a manual control, for generating an electrical voltage (T) proportional to the predetermined value of the tension or draught of the strip, and a second multiplier device (21) connected to the generator (13) and to the output of the first multiplier device (20).

8. Device according to any one of the preceding claims, further including means for detecting the inertial couple (C_J) acting on the tensioning arm (3), characterised in that the detector means include first and second accelerometers (10, 11) carried by the tensioning arm (3) on opposite sides of the pivot axis.

9. Device according to Claim 8, in which the drive means include a direct current motor (6) and the regulating means include a current regulator circuit (26) arranged to cause a current flow in the motor (6) which is substantially equal to a reference current (I) characterised in that the processing and control unit

(12) further includes:

a couple regulating circuit (23) connected to the couple sensor means (5) and to the means for generating the reference couple (13, 8, 20, 21) for outputting a couple error signal (ε_C), and

a summing circuit (24) connected to the couple regulating circuit (23), to the means for generating the reference couple (13, 8, 20, 21) and to the accelerometers (10, 11) and providing the current regulating circuit (26) with a current reference signal (I) proportional to the sum of the reference couple (Q_K), the couple error (ε_C) and the inertial couple (C_J) of the tensioning arm (3).

0161223

FIG_1

FIG.2